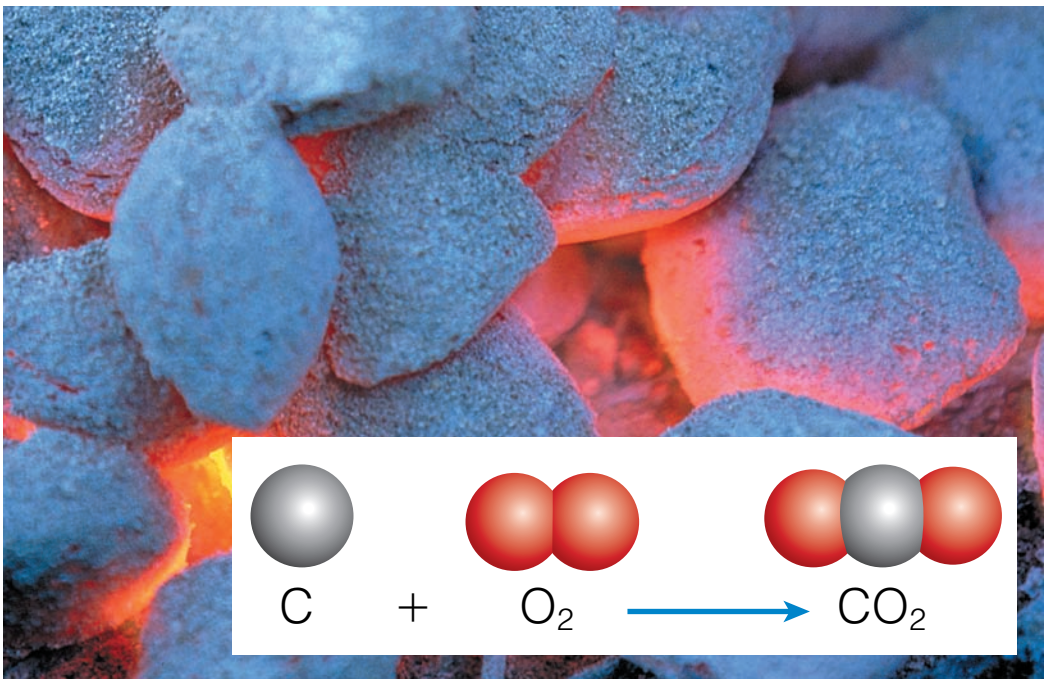
CHAPTER 3

Types of Chemical

Getting Ready...

- Name one chemical reaction you are familiar with. What happens during that reaction?
- What are some clues that a chemical reaction has occurred?
- Write one chemical formula that you know. Explain what the symbols mean.
- Why do chemists all over the world understand the short forms for various elements?



Science Log

Think back to some of the chemical reactions you have observed in class. Pick several that you remember. For each of these, describe in one sentence what the reactants and products were. As you read this chapter, you will see some different ways to describe what you saw.

Chemical reactions can be so spectacular! Most of us enjoy a colourful show of fireworks. And did you ever have sparklers for a special party?

Some chemical reactions give off light in a variety of colours; others produce sounds.

We use chemical reactions to treat and prevent disease, improve our food supply, purify water, and produce a wide variety of consumer goods. The more we learn about such reactions, the easier it is to use them with minimum risk.

It also helps to know how to describe different reactions. All chemical reactions involve changes in elements and compounds. This chapter will explain how to record what changes occur to elements and compounds during a reaction.

Just as your friends and family know you by a given name — and often by a nickname, too — most chemical compounds have an official name and a common one. For example, do you ever add *sodium hypochlorite* to your laundry? A chemist knows the compound by that name; you probably know it by its common name — bleach.

In this chapter you will investigate many chemical reactions and learn different ways to describe them. You will also learn some of the universal language chemists use to describe what occurs during a chemical reaction.

Reactions

Sparklers use a chemical reaction.

What You Will Learn

In this chapter you will learn:

- how to represent chemical equations using words and chemical formulas
- how to identify and describe different types of reactions
- how to recognize chemical formulas for some commonly occurring compounds
- why scientists use balanced chemical equations
- how the Law of Conservation of Mass applies to chemical reactions

Why It Is Important

- We live in an age of technology. Chemical reactions make modern technologies possible. Learning how to express and interpret the chemical reactions involved in common processes will enable you to make wiser choices about everything from foods and household products to transportation.

Skills You Will Use

In this chapter you will:

- represent simple chemical reactions using word equations
- identify composition, decomposition, combustion, and neutralization reactions
- carry out procedures and adapt those procedures where needed
- demonstrate a knowledge of WHMIS standards by applying proper handling techniques
- name common compounds from chemical formulas
- select and use appropriate methods of communication for ideas, plans, and results

Starting Point ACTIVITY

Flame Tests

Safety Precautions

- Tie back long hair and secure any loose clothing.
- Do this investigation on a fire resistant surface.
- Clean up the work area and wash your hands thoroughly at the end of activity.

What You Need

wooden splints
0.5 mol/L sodium nitrate solution
0.5 mol/L potassium nitrate solution
0.5 mol/L calcium nitrate solution
0.5 mol/L copper (II) nitrate solution
Bunsen burner
tongs
waste container safe for used splints

What to Do

1. Set up and light a Bunsen burner as demonstrated by your teacher
2. Use the tongs to remove one wooden splint that has been soaked in the sodium nitrate solution.
3. Briefly place the soaked splint in the blue part of the Bunsen burner flame. **Caution:** Do not leave the splint in the flame too long or it will start to burn.
4. Record the colour of light emitted by the sodium compound.
5. Place the used splint in the designated waste container.
6. Repeat steps 2 to 6 for the other solutions.

3.1 Word Equations

Disc CONNECT

To learn more about representing simple chemical reactions using word equations, load the student CD-ROM onto your computer. Launch the **Chemical Reactions** applet and follow the instructions.

Here is a summary of what you have learned so far.

- Chemical reactions can be simple (like powering a space shuttle) or complex (like taking an antacid).
- Chemical changes can be obvious (like burning a candle) or less noticeable (like the reaction that makes a cake rise).
- They can occur immediately (like explosives) or more slowly (like the ripening of a banana).

To describe these many different chemical reactions, chemists often use a convenient method known as a **word equation**. A word equation uses words to indicate what changed during the chemical reaction and what is produced.

READING Check

Why do chemists use word equations to represent chemical reactions?

Word equations are a simple way for chemists to describe chemical changes. They also help us recognize patterns that many reactions have in common.

Writing Word Equations

Word equations are always written in the same format.

- The left side of the equation lists all the reactants.
- The right side of the equation lists all the products.
- An arrow points from the reactants to the products. It shows that something is produced during the reaction.

READING Check

Describe the standard format for word equations.

all reactants → all products

All the reactants and all the products in a word equation are separated by a plus sign (+).

reactant 1 + reactant 2 → product 1 + product 2

Off the Wall

Zinc chloride solution is often used to enhance the detail in fingerprint analysis. Fingerprints developed with regular development compounds become fluorescent after being treated with zinc chloride.

Figure 3.1 Limestone caves are formed when the calcium carbonate in the stone combines with acids in rainwater. The product, calcium hydrogen carbonate, is washed away in water. This leaves behind empty caves. Read the next page to find the word equation for this.

Word Equations for Some Chemical Reactions

Let's look at some commonly occurring chemical reactions. The first reaction takes place inside your body. It is the key to converting the food you eat into the energy your body can use. The word equation for this reaction is written as:

oxygen + food (glucose) → carbon dioxide + water + energy

The equation is read as:

Oxygen and food (glucose) produce carbon dioxide and water and energy.

oxygen + glucose (food) → carbon dioxide + water + energy

Figure 3.2 During cellular respiration, glucose or food is broken down into water, carbon dioxide, and energy in a form that cells can use.

The second word equation describes a common chemical reaction that produces limestone caves:

carbonic acid + calcium carbonate → calcium hydrogen carbonate

This equation is read as:

Carbonic acid and calcium carbonate produce calcium hydrogen carbonate.

In Conduct an Investigation 2–B (on page 32), you observed many different chemical reactions. These chemical reactions can all be described using word equations. For example, when you added hydrochloric acid to mossy zinc, you may have noticed that the solution became warmer as the zinc dissolved, and a gas was released. The equation for this reaction is written as:

zinc + hydrochloric acid → zinc chloride + hydrogen gas + energy

This equation is read as:

Zinc and hydrochloric acid produce zinc chloride and hydrogen gas and energy.

READING Check

Do you always need more than one reactant or more than one product to have a chemical reaction?

Check Your Understanding

Key Terms

word equation

1. Copy each of the following word equations into your notebook. Beside each, write what you would say as you read the equation.

   (a) solid zinc + hydrochloric acid → hydrogen gas + zinc chloride

   (b) ammonium nitrate + sodium hydroxide → ammonium hydroxide + sodium nitrate

   (c) hydrochloric acid + sodium acetate → acetic acid + sodium chloride

3.2 Types of Reactions

Imagine you are preparing a cake from your favourite recipe, and you discover that you have run out of a few ingredients. If you know there are patterns in the way some of the ingredients go together, you can make substitutions for the missing ingredients. For example, yogurt could be used instead of an egg to increase the lightness of a cake.

In a similar way, chemists know there are patterns in the way certain elements and compounds go together. They use these patterns to group different types of chemical reactions. Grouping chemical reactions is useful for several reasons. First, it allows chemists to predict the product of an unknown chemical reaction. Second, it helps them to understand the behaviour of substances in a chemical reaction. This section will deal with the four most common reaction types.

READING Check

Give two reasons why it is useful for chemists to understand reaction types.

Simple Composition Reactions

Figure 3.3 shows what happens when magnesium is ignited in the presence of oxygen. During this reaction, there are two reactants. The first one is the element magnesium. The other is the element oxygen.

If you held the magnesium in the flame, you might observe a reaction taking place. The resulting product would be the compound magnesium oxide. The reaction would also produce energy in the form of bright light. The word equation for this reaction is:

magnesium + oxygen → magnesium oxide + light + thermal energy

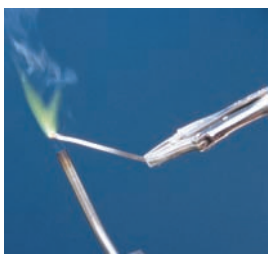


Figure 3.3 When magnesium burns, there is an obvious chemical reaction between two elements. This is an example of a simple composition reaction. What are the reactants? What are the products?

Internet CONNECT

www.mcgrawhill.ca/links/science.connect2

Magnesium oxide is a compound with a very high melting point. This makes it useful in the manufacture of many industrial products. Research and report on some of the uses of magnesium oxide. Go to the above web site, then to Internet Connects, Unit A, Chapter 3, and then to Magnesium Oxide.

In a **simple composition** reaction, two or more simple elements combine to form a compound. Whenever you see two elements as reactants, you know that the reaction is a simple composition reaction.

In a simple composition reaction, the product is always a compound. If we use the letters A and B to represent two different elements, a simple composition reaction is written in this way:

$$\text{Element}_1 + \text{Element}_2 \rightarrow \text{Compound}$$
$$A + B \rightarrow AB$$

Most simple composition reactions are exothermic, meaning that some form of energy is released. It is wise to know about this type of chemical reaction before trying it in a laboratory.

READING Check

In your own words, define a simple composition reaction.

Simple Decomposition Reactions

During electrolysis, water is broken down into hydrogen gas and oxygen gas. Electric energy is needed to drive this reaction. This makes it an endothermic reaction. The word equation for this reaction is:

water + electric energy → hydrogen gas + oxygen gas

A reaction that breaks a compound into its component elements is known as a **simple decomposition** reaction. Whenever you see a compound as the only reactant, you know the reaction is a simple decomposition reaction. In a simple decomposition reaction, the products are always elements. If we use the letters C and D to represent two different elements, a simple decomposition reaction is written in this way:

$$\text{Compound} \rightarrow \text{Element}_1 + \text{Element}_2$$
$$AB \rightarrow A + B$$

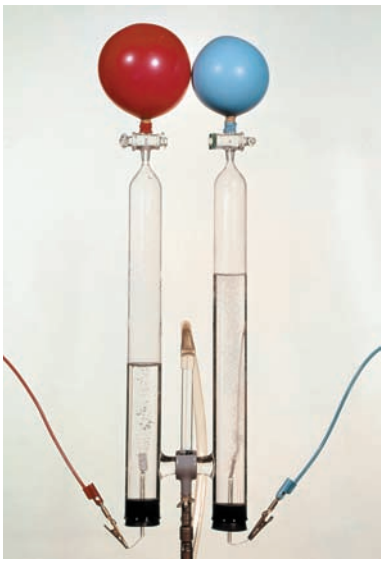
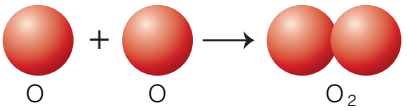


Figure 3.5 The process of electrolysis is an example of a simple decomposition reaction. Electric energy is required to drive this reaction, which also makes it an endothermic reaction.

simple composition reaction



simple decomposition reaction

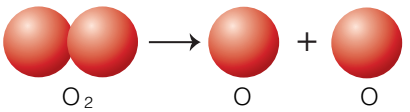


Figure 3.4 A simple composition reaction involves the combination of two elements. A simple decomposition reaction involves the breaking apart of a compound.

READING Check

In your own words, define a simple decomposition reaction.

Most decomposition reactions are endothermic, meaning that energy is absorbed.

You have learned about composition reactions, in which elements are "put together." You also know something about decomposition reactions, in which compounds are "broken apart." In Conduct an Investigation 3–A, you will investigate what happens to elements and compounds in these two reaction types.

DidYouKnow?

Knowing about reaction types makes it possible for scientists and technologists to predict the products of chemical reactions. Sophisticated lab equipment also helps to protect the investigating scientist.

In the past, experimenters sometimes endangered their health by performing chemical reactions without any advance knowledge of the chemicals that would be produced. English chemist Sir Humphry Davy (1778–1829) frequently inhaled gaseous chemicals he produced in the lab. He experimented with breathing pure carbon dioxide gas, and nearly suffocated himself when inhaling pure hydrogen gas. He also inhaled nitrous oxide gas, which has anaesthetic properties.

Figure 3.6 Sir Humphry Davy

CONDUCT AN

INVESTIGATION 3–A

SKILL CHECK

Initiating and Planning

Performing and Recording

Analyzing and Interpreting

Communication and Teamwork

Making It and Tearing It Down: A Composition/Decomposition Reaction — Teacher Demonstration

In a decomposition chemical reaction, a compound is broken down into the elements that make it up. The electrolysis of water is one example of a decomposition reaction. The chemical equation for this reaction is $2H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)}$.

Hydrogen peroxide ($H_2O_{2(l)}$) is a commonly used disinfectant that can also be decomposed into its elements. In Part 1 of this activity, you will investigate the decomposition of this chemical compound.

Part 2 of this investigation demonstrates how chemistry can be used at home. Some teaspoons, especially ones made a number of years ago, are made of silver ($Ag_{(s)}$). Silver tarnishes when exposed to hydrogen sulfide gas ($H_2S_{(g)}$), which is present in small amounts in air.

The black on a tarnished spoon is silver sulfide ($Ag_2S_{(s)}$). You can buy commercial tarnish removers to remove this silver sulfide. In this activity, you will investigate how common household chemicals — aluminum foil, baking soda, and boiling water — can accomplish the same task.

Safety Precautions

- Tie back long hair and secure any loose clothing.
- Clean up work area and wash your hands thoroughly at the end of the investigation.

Apparatus

test tube
test tube holder
graduated cylinder
scoopula
electric kettle
tarnished silver teaspoon
Styrofoam™ coffee cup
hot pads or oven mitts
equal arm or electronic balance

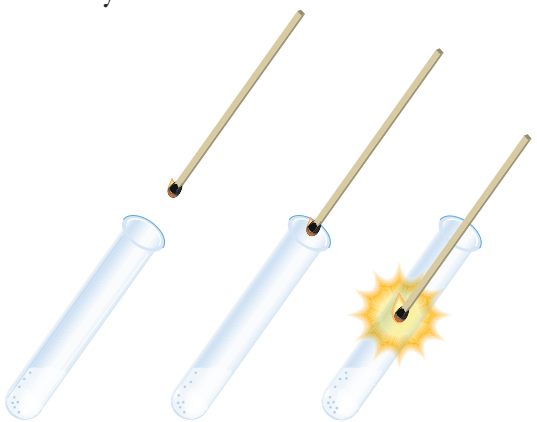
Materials

2 mL 3% hydrogen peroxide solution
trace amount magnesium dioxide solid
wooden splint
matches
100 mL boiling water
aluminum foil 30 x 30 cm (enough to fit the coffee cup)
1 g of sodium bicarbonate (baking soda)

Procedure

Part 1: Decomposition Reaction

1. Set the test tube securely into the test tube holder.
2. Use a graduated cylinder to add 2 mL of 3% hydrogen peroxide solution to the test tube.
3. Use the scoopula to add a trace amount of magnesium dioxide to the test tube. Record your observations.
4. Use the match to light the wooden splint. Insert the burning splint into the test tube. Record your observations.



Test for oxygen gas.

5. Extinguish the flame but splint should still be "glowing." Insert the glowing splint into the test tube and record your observations.

6. Dispose of the used wooden splints as directed by your teacher.

Part 2: Household Chemical Reaction

7. Cut a 9 x 9 cm square of aluminum foil. Crumple it and place it in the bottom of a Styrofoam™ cup.

8. Boil approximately 100 mL of water in the electric kettle.

9. Place 100 mL of boiling water into the coffee cup.

10. Mass 1 gram of sodium bicarbonate (baking soda) and add it to the boiling water.

11. Place a tarnished silver spoon into the coffee cup. It must be touching the aluminum.

12. Record your observations, including the odour released by this chemical reaction.

13. Dispose of the chemicals as directed by your teacher.

Analyze

1. Which elements (gases) were formed when hydrogen peroxide ($H_2O_{2(l)}$) was decomposed?
2. Describe what happened when you placed the tarnished spoon into the solution of boiling water and baking soda.
3. Describe the odour that was released during the chemical reaction that removed the tarnish from the silver spoon.

Conclude and Apply

1. What can you infer from your observation that the glowing splint burst back into flames?
2. Why is the chemical change in Part 1 considered to be a decomposition reaction?
3. What evidence did you gather that would lead you to believe that a chemical reaction occurred in Part 1 of this investigation?
4. The chemical and word equations for the removal of tarnish are summarized below. Which product might account for the smell that was produced by this chemical reaction?

$$3Ag_2S_{(s)} + 2Al_{(s)} \rightarrow 6Ag_{(s)} + Al_2S_{3(s)}$$

silver sulfide + aluminum → silver + aluminum sulfide

5. Identify two pieces of evidence that would lead you to believe that a chemical reaction occurred in Part 2 of this investigation.

Combustion Reactions

When you light a candle, the candle wax burns in the presence of oxygen to produce carbon dioxide and water. This is one example of a combustion reaction or burning. Combustion always occurs in the presence of oxygen.

Combustion also occurs when you burn fuel to power a car. The word equation for the combustion of gasoline (octane) is:

gasoline (octane) + oxygen → carbon dioxide + water vapour + energy

The same type of reaction occurs when you light a butane lighter. The word equation in this case is:

butane + oxygen → carbon dioxide + water vapour + energy

Oil and natural gas are fossil fuels. This means that they come from the accumulated remains of plants and animals from prehistoric times. Fossil fuels form very slowly, which is why many scientists believe we will run out of them. We use them up much more quickly than they can form.

Figure 3.7 Each of these items is a product of the petroleum industry.

Neutralization Reactions

In Chapter 2, you looked at some everyday chemical reactions, such as taking an antacid to relieve acid indigestion. This is an excellent example of a neutralization reaction. In a neutralization reaction, an acid reacts with a base to produce a form of salt and water. The word equation for a neutralization reaction is:

acid + base → salt + water

READING Check

Name another common term for a combustion reaction.

Did You Know?

76 L of petroleum can provide the gasoline to drive a vehicle 485 km, *or* it can produce 24 shirts, 5 m^2 of carpeting material, 2 automobile tires, 30 m of 1.3 cm diameter rope, 12 windbreakers, 2 tents, 4 sleeping bags, 6 duffel bags, 1 blanket, 4 sweaters, and 15 parkas!

Try This!

Do *one* of the following.

1. Collect the items outlined in the Did You Know? Measure the area covered by all of these items.
2. Measure the distance from your school to Ottawa. Assume that you are driving a small compact car that gets 10 km/L of gas. How many litres of gasoline would it take to drive from your school to Parliament Hill? List the items that this number of litres of gasoline might also produce.

When you take an antacid, the magnesium hydroxide in the tablet reacts with the hydrochloric acid in your stomach. This neutralization reaction is written as:

hydrochloric acid + magnesium hydroxide → magnesium chloride + water

You may be surprised to know how many neutralization reactions occur all around you every day. They are involved in many natural, household, and industrial products and processes.

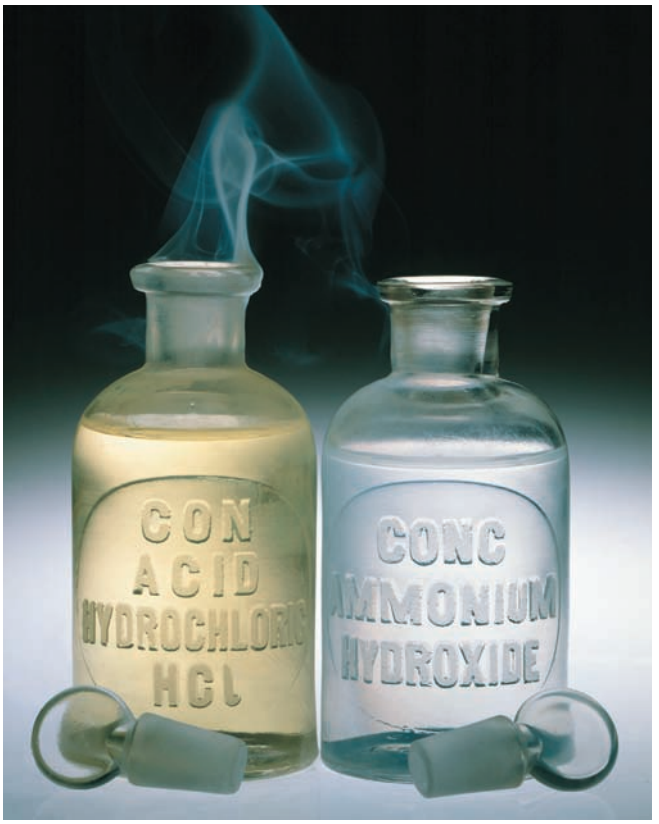


Figure 3.8 Many acid–base reactions produce water and a form of salt. The white cloud of ammonium chloride seen here is a product of the reaction of hydrochloric acid and ammonia. What WHMIS symbols should be on these bottles?

READING Check

In a neutralization reaction, an acid and a base react to form two products. Name the products.

Check Your Understanding

Key Terms

simple composition
simple decomposition

1. Read this list of chemical reactions. Identify the ones that show simple composition reactions.

   (a) methane gas + oxygen gas → carbon dioxide + water

   (b) solid calcium + oxygen gas → solid calcium oxide

   (c) solid sodium chloride → solid sodium + chlorine gas

   (d) solid sodium hydroxide + liquid acetic acid → sodium acetate (a salt) + water

   (e) solid magnesium + oxygen gas → magnesium oxide

   (f) hydrogen gas + oxygen gas → water

2. **(a)** Explain the following two equations.

   $A + B \rightarrow AB$

   $CD \rightarrow C + D$

   (b) Which one shows the general format of a simple composition reaction?

   (c) Which one shows a simple decomposition reaction?

3.3 Formulas for Common Compounds

READING Check

Why do we need a common international language when we talk about chemical reactions?

What if you spoke a language that no one else could understand? How would you communicate with your friends? Scientists around the world faced this problem when they started sharing information about chemicals and chemical reactions. Because scientists speak many different languages, they created a common language that would allow them to communicate with one another. This common language became the basis of what you are learning about in this chapter.

Chemical Names and Formulas

During a composition reaction you might add zinc powder to sulfur powder and then apply heat. This composition reaction would produce a compound called zinc sulfide. The word equation for this reaction is:

sulfur + zinc → zinc sulfide

When you write a word equation like this, you are using what is known as the **chemical name** for each of the reactants and products. When you look at the periodic table, you will see the chemical names of all the elements along with their chemical symbols. Each element has a symbol that consists of one capital letter or one capital and one lower-case letter. In this example, you have sulfur (S) and zinc (Zn).

DidYouKnow?

Substances can be in the form of a solid, liquid, or gas. These are known as physical states or states of matter. Many periodic tables show a symbol called a subscript beside each element. This subscript indicates the state in which an element is normally found. For example, the element zinc (Zn) would appear on the periodic table with an $_{(s)}$, indicating that zinc is normally found as a solid.

science.connect 1 used the following subscripts:

- $_{(s)}$ to indicate a solid
- $_{(l)}$ to indicate a liquid
- $_{(g)}$ to indicate a gas

A fourth subscript — $_{(aq)}$ — is used to indicate an aqueous solution, which is a substance dissolved in water.

Most chemical compounds are named according to the major elements they contain. Information about the chemical composition and structure of a compound is given by its **chemical formula**. In the above example, the product is the compound zinc sulfide, which has the chemical formula ZnS.

The rule for naming compounds like this is to name the metal first — zinc — followed by the name of the non-metal. The name of the non-metal is changed to "ide"— sulfide.

You could now replace the names of the reactants with their chemical symbols, and the product with its chemical formula. When writing formulas, remember to use a subscript to indicate the state of the material. In this example, we are dealing with solids, which are shown as $_{(s)}$. The chemical equation would look like this:

$$S_{8(s)} + 8Zn_{(s)} \rightarrow 8ZnS_{(s)}$$

READING Check

Explain the difference between chemical names and chemical formulas.

Common Names

Not everyone is a scientist, so many chemical compounds are often identified by a **common name**. These names are easier to use, and they have existed since before the international naming system was created. You already know many chemicals by their common names. As a student of chemistry, you will learn some chemical names. For instance, the common name for sodium chloride ($NaCl_{(s)}$) is salt. Water is the common name for dihydrogen monoxide ($H_2O_{(l)}$).

Look at Table 3.1 to see how many more common and chemical names you already know.

Common Name	Chemical Name	Chemical Formula
alcohol	ethanol	$C_2H_5OH_{(l)}$
antifreeze	ethylene glycol	$CH_2H_6O_{2(l)}$
baking soda	sodium bicarbonate	$NaHCO_{3(s)}$
chalk, limestone, marble	calcium carbonate	$CaCO_{3(s)}$
club soda	carbonic acid	$H_2CO_{3(l)}$
Epsom salt	magnesium sulfate	$MgSO_{4(s)}$
laughing gas	dinitrogen monoxide	$N_2O_{(g)}$
lye or caustic soda	sodium hydroxide	$NaOH_{(s)}$
natural gas	methane	$CH_{4(g)}$
quartz	silicon dioxide	$SiO_{2(s)}$
rubbing alcohol	isopropyl alcohol	$C_3H_7OH_{(l)}$
table salt	sodium chloride	$NaCl_{(s)}$
salt substitute	potassium chloride	$KCl_{(s)}$
sugar	glucose sucrose (table sugar)	$C_6H_{12}O_{6(s)}$ $C_{12}H_{22}O_{11(s)}$
water	dihydrogen oxide	$H_2O_{(l)}$

Table 3.1 Chemical Names and Formulas of Some Common Chemicals

READING Check

Copy down the chemical formulas for five of the chemical compounds listed in Table 3.1. Beside each, list the elements contained in the chemical along with their chemical symbols.

Internet CONNECT

www.mcgrawhill.ca/links/science.connect2

Use the Internet to find out about other chemical names and formulas. Go to the above web site, then to Internet Connects, Unit A, Chapter 3, and then to Molecule of the Month.

Check Your Understanding

1. Investigate one of the chemicals below. Use your periodic table, Table 3.1, and other chemistry textbooks to describe the chemical as thoroughly as possible.

- Where might it be used?
- How many different elements does it contain? How many atoms of each? How many atoms in total?
- Should it be labelled with a WHMIS symbol? If so, which one(s)?
- What is its common name? Its chemical name?

(a) $CaCO_{3(s)}$

(b) $SiO_{2(s)}$

(c) $C_2H_5OH_{(l)}$

(d) $CH_{4(g)}$

(e) $C_{12}H_{22}O_{11(s)}$

Key Terms

chemical name
chemical formula
common name

3.4 Chemical Equations

Think back to some of the chemical reactions you have seen in this chapter and the previous one. During the activities, you observed colours changing, bubbles appearing, and precipitates forming. You may also have detected odours being given off and energy being released in the form of light or heat.

In some chemical reactions, matter may appear to be destroyed. Is it really? What happens to the masses of the reactants and the products during a chemical reaction? That is what a French chemist named Antoine Lavoisier asked more than 200 years ago.

The Law of Conservation of Mass

READING Check

Why did Antoine Lavoisier use a sealed flask for his investigation?

In the 1700s, Antoine Lavoisier (1743–1794) placed a carefully measured mass of solid mercury (II) oxide into a sealed flask. When heated, the compound produced liquid mercury and oxygen gas. When this chemical reaction was finished, Lavoisier measured the mass of each of the products. He found that the total mass of the two products was identical to the mass of the reactants. The following word equation shows this reaction. The masses of the reactant and products are shown below the word equation:

solid mercury (II) oxide	→	oxygen gas	+	liquid mercury
10.0 g		0.7 g		9.3 g

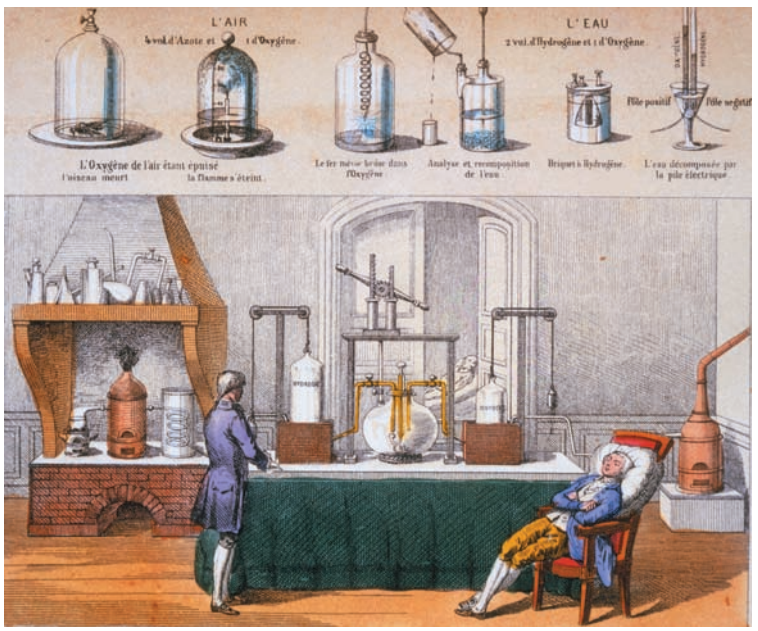


Figure 3.9 Antoine Lavoisier used precise balances for his investigations. This led to the Law of Conservation of Mass.

Lavoisier concluded that the atoms in a chemical reaction were just rearranged, not destroyed. This conclusion is known as the **Law of Conservation of Mass**, which states:

> In a chemical reaction, matter is not created or destroyed. If you start a reaction with 10 g of reactants, you will end up with 10 g of products.

Try This!

Develop an activity during which you repeat Antoine Lavoisier's investigation. Use safe chemicals such as baking soda and vinegar. Allow the gas to escape. Check the mass of the chemicals before and after. What do your results suggest about the mass of carbon dioxide that was released?

Staying Balanced

When chemists write chemical equations, they do not usually use word equations. When dealing with chemicals, this method is not exact enough. Using a word equation would be like writing a word equation to explain how to build a house.

energy + wood + concrete + steel + metal → house

The builder of such a house would soon have many questions. How much of each material would she need?

Chemists feel the same way. They need to know the exact quantities of chemicals to use when chemical reactions are used in technological processes. Word equations do not state the quantities of the substances needed. They also do not reveal the types of atoms involved. Compare these two equations:

vinegar + baking soda → sodium acetate + water + carbon dioxide gas

$CH_3COOH_{(aq)} + NaHCO_{3(s)} \rightarrow NaC_2H_3O_{2(l)} + H_2O_{(l)} + CO_{2(g)}$

When the chemical formulas of the reactants and products are used, then you can determine exactly what atoms make up the reactants and products. The Math Connect on this page and the one on the next page will help you learn to analyze such equations.

Disc CONNECT

To learn more about balancing equations, load the student CD-ROM onto your computer. Launch the **Chemical Reaction** applet and follow the instructions. If possible, do either this applet or the Find Out activity on page 55 before working on the Math Connects that follow.

READING Check

What is the advantage of using equations with formulas instead of simple word equations?

Math CONNECT

Checking the Balance of Simple Equations

A **balanced chemical equation** has the same elements and the same number of atoms of each element on both sides.

Sample Problem

The equation that follows shows what happens when carbon and oxygen gas go through a chemical reaction. Is the equation balanced?

$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$

Steps in Solving It

1. *What elements are on the reactant side?*
   The letters shown are C and O. If you cannot remember what these stand for, check a copy of the periodic table. C is the element carbon. O is the element oxygen.
2. *How many atoms of each element are on the reactant side?*
   There is no subscript beside carbon. This means that there is only one atom of carbon. The subscript 2 ($_2$) beside oxygen tells you there are 2 atoms of oxygen.
3. *What elements are on the product side?*
   Again, there is a C and an O.
4. *How many atoms of each element are on the product side?*
   There is no subscript with C, so there is only one atom of carbon. O has a subscript — 2. So there are two atoms of oxygen.
5. *Is this equation balanced?*
   reactant side = 1 atom of carbon, 2 of oxygen
   product side = 1 atom of carbon, 2 of oxygen
   Yes, the equation is balanced.

Solve These

Use the example above to help you check whether the following equations are balanced. Be sure to show your thinking and calculations.

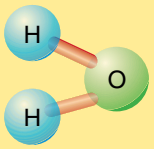
1. $Cl_{2(g)} + H_{2(g)} \rightarrow 2HCl_{(g)}$

2. $FeO_{(s)} \rightarrow Fe_{(s)} + O_{2(g)}$

Math CONNECT

Checking the Balance of Complex Equations

Water electrolysis is an example of a simple decomposition reaction. You observed such a reaction during Conduct an Investigation 2–B on page 32. Although the reaction is simple, the equation that represents it is not so simple. This Math Connect will show you how to read and check the balance of such equations.



This molecular model of a water molecule ($H_2O_{(l)}$) clearly shows there are two hydrogen (H) atoms and one oxygen (O) atom in each molecule of water.

The equation for showing the decomposition of water is $2H_2O_{(l)} \rightarrow O_{2(g)} + 2H_{2(g)}$. In such equations, the numbers in front of the chemical formulas are called coefficients. **Coefficients** are used to balance those individual atoms. In $2H_2O_{(l)} \rightarrow O_{2(g)} + 2H_{2(g)}$, the 2 in front of the H is a coefficient. It tells how many H_2 molecules are present.

Sample Problem

Read the equation. Identify and count the atoms on each side. Is it balanced?

$2H_2O_{(l)} \rightarrow O_{2(g)} + 2H_{2(g)}$

Steps in Solving It

1. *What elements are on the reactant side?*
   The letters shown are H and O. If you cannot remember what they stand for, check a copy of the periodic table. They are hydrogen and oxygen.
2. *How many atoms of each element are on the reactant side?*
   The 2 in front of $H_2O_{(l)}$ makes this tricky. The large 2 means that there are 2 H_2 and 2 O. Let's deal with each one separately.

   $2H_2 = H_2 + H_2$

   The subscript 2 ($_{(2)}$) beside hydrogen tells that there are two hydrogen atoms in each H_2 molecule.

   $H_2 = H + H$

   And there are two of these in the chemical name. So

   $2H_2 = H + H + H + H = 4$ hydrogen atoms

   $2O = O + O = 2$ oxygen atoms
3. *What elements are on the product side?*
   Again, you see H and O. These are hydrogen and oxygen.
4. *How many atoms of each element are on the product side?*

   $O_2 = O + O$

   The 2 in front of $H_{2(g)}$ makes this tricky. The large 2 means that there are 2 $H_{2(g)}$. Let's deal with each one separately.

   $2H_2 = H_2 + H_2$

   The subscript 2 ($_{(2)}$) beside hydrogen tells that there are two hydrogen atoms in each H_2 molecule.

   $H_2 = H + H$

   And there are two of these in the chemical name. So

   $2H_2 = H + H + H + H = 4$ hydrogen atoms
5. *Is this equation balanced?*
   reactant side = 2 oxygen atoms, 4 hydrogen atoms

   product side = 2 oxygen atoms, 4 hydrogen atoms

   Yes, the equation is balanced.

Solve These

Use the example above to help you check whether the following equations are balanced. Be sure to show your thinking and calculations.

1. $2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$

2. $2Al_{(s)} + 3I_{2(s)} \rightarrow 2AlI_{3(s)}$

3. $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$

Find Out ACTIVITY

Working with Chemical Compounds

In this activity, you will build models of reactants and products to see how they are affected by chemical reactions.

SKILL CHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Safety Precautions

- Clean up the work area and wash your hands thoroughly at the end of the activity.

What You Need

molecular model kit

or

foam balls (different sizes and/or colours)

toothpicks

What to Do

1. Word equations for four different chemical reactions are shown here. For each reaction, use the molecular model kit or foam balls and toothpicks to build models of the reactants and products. Refer to the molecular model of a water molecule shown earlier in this section. This will help you get started on your model.

Reaction 1

$2H_2O_{(l)} \rightarrow O_{2(g)} + 2H_{2(g)}$

Reaction 2

$CH_{4(g)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(g)}$

Reaction 3

$N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$

Reaction 4

$2HgO_{(g)} \rightarrow Hg_{(s)} + O_{2(g)}$

2. Start with Reaction 1. Build a model of the reactant(s) in the equation.
3. Take apart your model of the reactant(s). Now, use the same balls and toothpicks to create the products of that reaction.
4. Repeat Steps 2 and 3 for each of the reactions listed.

What Did You Find Out?

1. Which reactions are not balanced? How do you know?
2. Explain in your own words how this activity illustrates the Law of Conservation of Mass.

Check Your Understanding

1. Look carefully at the equations below. Which ones are balanced? Show your thinking and any calculations.

   (a) $Cl_{2(g)} + 2KI_{(g)} \rightarrow 2KCl_{(g)} + I_{2(s)}$

   (b) $3Li_{(s)} + 2H_2O_{(l)} \rightarrow 2LiOH_{(l)} + H_{2(g)}$

   (c) $Zn_{(s)} + H_2SO_{4(l)} \rightarrow ZnSO_{4(s)} + H_{2(g)}$

2. In your own words, explain why equations must be balanced. Compare a balanced chemical equation to what actually happens during the reaction.
3. Look back at the four reactions in the Find Out activity above. Classify each reaction as a composition reaction, decomposition reaction, combustion reaction, or neutralization reaction.

Key Terms

- Law of Conservation of Mass
- balanced chemical equation
- coefficients

CHAPTER

3 Review

Key Terms

word equation
simple composition
simple decomposition
chemical name
chemical formula
common name
Law of Conservation of Mass
balanced chemical equation
coefficients

Reviewing Key Terms

If you need to review, the section numbers show where these terms were introduced.

1. In your notebook, write the correct term or terms to complete each of the following sentences.

(a) Although two or more _____ are needed for a simple composition reaction, only one product results. (3.2)

(b) Simple _____ reactions produce a compound, while simple _____ reactions break down compounds. (3.2)

(c) Reactions follow patterns. Studying these _____ _____ helps a chemist know what to expect. (3.2)

(d) If a chemical appears on the periodic table, it is a(n) _____ . (3.2)

(e) Chemicals represented by symbols are called _____ _____ . (3.3)

(f) Chemicals are not created or destroyed in a chemical reaction. This is known as the _____ (5 words). It was first proposed by _____ . (3.4)

Understanding Key Ideas

Section numbers are provided if you need to review.

2. This chapter examines simple composition, simple decomposition, combustion, and neutralization reactions. Copy the data table shown here into your notebook. Fill it in to describe all four types of reactions. (3.2)

Reaction Type	Reactant(s)	Product(s)	Energy Released (exothermic) or Energy Required (endothermic)

3. Give the chemical names and chemical formulas for the following compounds. (3.3)

(a) salt

(b) water

(c) sugar

(d) baking soda

(e) chalk

(f) marble

4. Write down a word equation for one chemical reaction in this chapter. Then list:

(a) the reactants

(b) the products (3.1)

5. In your own words, explain the Law of Conservation of Mass. (3.4)

6. Explain how a chemical equation can be written in a universal language understandable by chemists around the world. (3.4)

Developing Skills

7. Why is it important to balance a chemical equation? (3.4)

8. Classify each of the following chemical reactions as a simple composition or simple decomposition reaction. (3.2)

   (a) $X + Y \rightarrow XY$

   (b) $CD \rightarrow C + D$

   (c) Energy in the form of heat, electricity, or light must usually be added to this type of reaction.

   (d) Two or more elements combine to form a compound in this reaction type.

   (e) A chemical is broken down into its component elements.

   (f) Oxygen in the air combines with iron to form rust.

   (g) Heat or light are often given off in this type of reaction.

   (h) Water breaks down into hydrogen and oxygen gases.

Problem Solving/Applying

9. Think of an analogy to explain simple composition and decomposition reactions to your younger sibling or friend. For example, these two reaction types can be compared to dancing. A simple composition reaction is like two people coming together to dance. A simple decomposition reaction occurs when the song ends and the two people return to their seats. Now you think of one. (3.2)

10. Is the following equation balanced? Explain your answer. (3.4)

$$Mg_{(s)} + 2HCl_{(l)} \rightarrow MgCl_{2(s)} + H_{2(g)}$$

Critical Thinking

11. The mass of the reactants in a chemical reaction will equal the mass of the products. Is the same always true for the volumes of the reactants and the products? (3.4)

12. In the reaction of carbon with oxygen, one carbon atom reacts with one oxygen molecule. If 20 billion atoms of carbon react with 30 billion molecules of oxygen, will all the reactants be used up? Explain. (3.4)

13. Why are composition reactions mostly exothermic? Why are decomposition reactions mostly endothermic? Investigate this question in your school library. (3.2)

Pause & Reflect

1. Review how you answered the Getting Ready questions at the beginning of the chapter. How has your thinking changed? How would you answer these questions now that you have investigated the topics in this chapter?
2. Now that you know much more about chemical reactions, how does this affect your thinking about the products you use every day? How will your new knowledge change the way you choose these products?